October 16 and 17, 1903, one which developed from scarcely visible indications into a gale on December 30, 1900, and one which disappeared, or "filled up," as it is technically called, on February 6, 1904. The conclusion was drawn that the suggested extension of the area of observation by means of wireless telegraphy from ships crossing the Atlantic would not immediately place forecasting in the position of an exact science, but would add greatly to the facilities for studying the life-history of depressions.

The irregularities and uncertainties illustrated by the examples given might be attributed in part to the complexities of pressure due to the irregular distribution of land and sea in the northern hemisphere. Charts of the mean isobars for the world for January and July showed greater simplicity of arrangement in the southern hemisphere, where the ocean was almost uninterrupted, than in the northern hemisphere, where there were alternately large areas of sea and land. The comparative simplicity of the south as compared with the north was also illustrated by a chart representing an attempt at a synoptic barometric chart for the world for September 21, 1901.

The simplification of the barometric distribution at successively higher layers of the atmosphere, as illustrated by Teisserenc de Bort's chart of mean isobars at the 4000-metre level, was pointed out, and illustrations were also given of the method of computing the barometric distribution at high levels from observations at the surface, using data obtained from observations at high-level observatories, or those made with balloons and kites.

Some indication of the connection between the complexity of the surface and the simplicity of the upper strata might be established by means of careful observations of the actual course of air upon the surface and the accompanying weather conditions.

The actual course of air along the surface was often misunderstood. The conventional S-shaped curves representing the stream lines from anticyclonic to cyclonic regions were shown to be quite incorrect as a representation of the actual paths of air along the surface. A diagram contributed to the *Quarterly Journal of the Royal Meteorological Society*[1] showed the computed paths for special case of a storm of circular isobars and uniform winds, travelling without change of type at a speed equal to that of its winds. An instrument made by the Cambridge Scientific Instrument Company to draw the actual paths of air for a number of different assumptions as to relative speed of wind and centre, and of incurvature of wind from isobars, was also shown, and the general character of the differences of path exhibited under different conditions was discussed.

In illustration of the application of these considerations to practical meteorology, it was noted that rainfall is an indication of the existence of rising air, and conversely the disappearance of cloud may be an indication of descending air. It was further noted that if the ascent and descent of air extended from or to the surface, the actual paths of air along the surface, as traced from the direction and speed of the winds, ought to show convergence in the case of rising air and divergence in the case of descending air.

The chart for April 16, 1903, was referred to for an obvious case of dilatation or divergence of air from a centre corresponding with fine weather, the centre of the area of divergence being specially marked "no rain," and the actual trajectories or paths of air for two different travelling storms were contrasted, to show how the rainfall might be related to the convergence of the paths of air. The two occasions selected were (1) the rapid travelling storm of March 24–25, 1902, and (2) the slow travelling storm of November 11–13, 1901.[2] The trajectories or actual paths of air for these two storms had been constructed from two-hourly maps drawn for the purpose from a collection of records of self-recording barographs, &c. Those for March 24–25 showed the paths to be looped curves with very little convergence, whereas those for the storm of November 11–13 showed very great convergence; so much so that if four puffs of smoke could be imagined starting at the same time from Aberdeen, Blacksod Point, Brest, and Yarmouth respectively, and travelling for twenty-four hours, they would find themselves at the end of the time enclosing a very small area in the neighbourhood of London.

Corresponding to this difference of convergence as shown by the paths was the difference of rainfall as illustrated by two maps showing the distribution of the rain deposited from the two storms. The first, with little convergence, gave hardly anywhere more than half an inch; the second, with its great convergence, gave four inches of rain in some parts of its area.

[1] The Meteroological Aspects of the Storm of February 26–27, 1903. *Q. J. R. Met. Soc.*, vol. xxix. p. 233; 1903.

[2] See Pilot Charts for the North Atlantic and Mediterranean, issued by the Meteorological Office. February, 1904.

BREATHING, IN LIVING BEINGS.[1]

It has been said that the most striking facts connected with respiration are its universality and its continuity. In popular language "the breath is the life." Breathing is not only a sign of life, it is a condition of its existence. Permanent cessation of breathing is regarded as a sign of death. Link up with this the icy coldness of death and you have two significant facts.

Respiration and calorification are therefore intimately related; in fact, calorification is one form of expression of the results of respiratory activity.

The popular view of respiration is an inference from what is observed in man and animals. During life the rise and fall of the chest goes on rhythmically from the beginning to the end. The respiratory exchanges effected in the breathing organs—lungs or gills—constitute "external respiration." This, however, scarcely touches the main problem, viz. what is called "internal respiration," or tissue respiration—*i.e.* the actual breathing by the living cells and tissues which make up a complex organism.

We are told that man does not live by bread alone. We know he requires, in addition, solids, fluids and air. Taking these to represent the three graces, then air is of all the graces best.

The higher animals have practically no reserve stores of air—unlike what happens with the storage of fats and proteids—and hence the necessity for mechanisms by which air is continually supplied to the living tissues, and also by which the waste product of combustion, viz. carbon dioxide, is got rid of. Closure of the wind-pipe, even for a few minutes, brings death with it from suffocation. The entrance of oxygen is prevented and the escape of carbon dioxide is arrested.

The process of breathing is common to all living beings —to plants and animals alike. It consists essentially in the consumption of oxygen by the tissues and the giving out of carbon dioxide. It is immaterial whether the animals or plants live in water or air, the principle is the same in both cases. Living active protoplasm demands a supply of oxygen.

All the world's a stage. The human body is at once a stage, and a tabernacle—a vast theatre—and the myriads of diverse cells of which it is composed, the players.

The cells or players, as active living entities, not only require food, but they require energy. The respiratory exchanges in and by the living cells provide the energy for the organism. This breathing by the cells is called "internal respiration." In a complex organism, therefore, the respiratory exchanges represent the algebraic sum of the respiratory activity of the several tissues that make up the organism. The various tissues, however, breathe at very unequal rates.

In one of his charming "contes philosophiques," Voltaire describes the visit of a giant of Sirius to our planet. Before reaching his journey's end he would have to traverse an aërial medium, and on arriving would see before him a fluid medium in continual movement, and tracts of solid land. After investigation—or no doubt he would be told, even though he was not personally conducted—that the water surface of this our globe is two

[1] Abstract of a discourse delivered at the Royal Institution of Great Britain by Dr. William Stirling.

and a half times greater than the land surface. He would discover that there are animals that live in air, others in water, and again others on land. Our visitor would find out that the respirable media are two—water and air—and that there are 210 parts of free oxygen in a litre of air, while there are only 3–10 dissolved in a litre of water.

Had Voltaire's friend paid us another visit during the present century, we should be able to tell him that the water of the Thames above London contains 7·40 c.c. of O per litre; at Woolwich only 0·25, the decrease being due to the pollution of the river. Putting it broadly, water contains only 3–10 parts per litre, while air contains 210. Water-breathers under good conditions have twenty times less O than air-breathers. It is as if air-breathers on land had the percentage of O_2 reduced to 1.

He would also be told that carbon dioxide—CO_2—is also remarkably soluble in water, and readily combines with certain bases present in water; thus water forms an admirable medium into which an animal may discharge its effete and poisonous irrespirable CO_2.

He would also be told that our blood contains 60 volumes per cent. of gases, and that there is more O and less CO_2 in arterial blood than in venous blood.

Perhaps the name of Sir H. Davy might be whispered to him, for he was one of the first to detect the presence of gases O and CO_2 in blood.

In story, one has heard of the "Quest of the Holy Grail." I have even listened with rapt attention to an entrancing lecture on the "Quest of the Ideal." For the cell, the quest is the "quest of oxygen," and it is not happy until it gets it.

We speak of a distinction between air-breathers and water-breathers. If, however, we push the matter to its ultimate issue, we find that all our tissues—and equally those of plants—live in a watery medium; in us the fluid lymph which exudes from our capillary blood-vessels, and in plants in the sap. Thus we come upon what at first seems a paradox, but is not so; all our cells not only live in water, but they live in running water. They are bathed everywhere by the lymph which is the real nutrient fluid for our cells. Thus, in its final form, all respiration is actually aquatic. The process of internal respiration, besides other conditions, requires the presence of a certain amount of water. In fact, all vital phenomena require the presence of water.

The unity and identity of the process in animal and vegetable cells, as the theatre of combustion, is the striking fact. The means by which the necessary oxygen is brought to the cells is as varied as the forms of animated organisms themselves. This function exists for the cells, and not the cells for the function.

If the mountain will not go to Mohammed, Mohammed must go to the mountain. There are, at least, two principles on which animal cells obtain oxygen.

The air or water containing air is carried to the cells. This is the principle adopted in the lower invertebrates, as in sponges and with regard to certain air-breathers such as insects.

The other principle is this, that an intermediary carries the respiratory oxygen from some more or less central localised or diffuse surface to the cells. This intermediary is the blood—an internal medium of exchange. The fluid part of the blood may carry the oxygen supply and remove the carbonic dioxide waste. This is the case in many of the invertebrates, and it reaches its highest development in the vertebrates. Hence in them the circulating and respiratory systems reach their fullest development.

In most invertebrates the fluid part of the blood contains the nutritive substances and also the oxygen and carbonic acid. In the vertebrates, the hæmoglobin of the red blood corpuscles carries the oxygen from the gills or lungs to the tissues, whilst the CO_2 is contained in and carried chiefly by the blood plasma from the tissues to the gills or lungs.

It is singular that in the cephalopods, such as the squid and cuttle-fish, the blood is bluish in tint; and this is due to the presence in the plasma of a respiratory pigment called hæmocyanin. This body has a composition like that of hæmoglobin, but copper is substituted for the iron of the hæmoglobin. Copper also exists in organic combination in the red part of the feathers of the plantain-eater or turaco.

The real aristocracy with genuine blue blood are the crab, lobsters, squids, and cuttle-fishes.

Perhaps one of the most striking ways of dissociating this accessory mechanism from the activity of the cell itself is by the use of a poison. When a person is poisoned by coal gas, what happens? The coal gas contains carbon monoxide. This gas does not poison invertebrate animals or plants. Still it kills vertebrate animals. Why? It does not kill by acting on the living cells, only by depriving them of oxygen and asphyxiating them. It combines with the respiratory pigment hæmoglobin. Chloroform, ether, and similar drugs destroy the actual life of the cell elements by destroying their irritability.

In 1771, Priestley found that air vitiated by combustion of a candle, or by the breathing of animals—such as mice—could be made pure or respirable again by the action of green plants.

Under certain conditions, however, Priestley found that plants gave off carbonic acid, and the air did not support combustion or animal life. He regarded these as "bad experiments," and he selected what he was pleased to regard as "good experiments," *i.e.* those in which the air, rendered impure by the respiration of animals, was rendered respirable by the action of green plants.

In 1779 John Ingen-Housz published his "Experiments on Vegetables, discovering their great power of purifying the common air in sunshine, and of injuring it in the shade and at night."

He confirmed Priestley's observations that green plants thrive in putrid air, and that vegetables could convert air fouled by burning of a candle, and restore it again to its former purity and fitness for supporting flame, and for the respiration of animals—or, as he puts it, "plants correct bad air."

In 1787 Ingen-Housz, an English physician at the Austrian court, found that only in daylight did green plants give off oxygen. In darkness, or where there was little light, they behaved like animals so far as exchange of gases is concerned, *i.e.* they used up oxygen and exhaled carbonic acid. He found also that all roots, when left out of the ground, yielded by day and by night foul air, *i.e.* carbonic acid.

In the same year, 1804—the year of Priestley's death—Nicolas Theodore de Saussure, a Swiss naturalist and chemist, published his "Recherches Chimiques sur la Végétation" (Paris, 1804), a veritable encyclopædia of experiments of the effects of air on flowers, fruits, plants, and vegetation generally, and on the effects of these on atmospheric acid.

It is an old adage—the exception proves the rule. The exception "probes" the rule as the surgeon's probe probes a wound. The tactus eruditus of the surgeon, by his probe—indeed an elongated tactile sense—enables him to discover the presence or absence of a body in a wound. Had Priestley used the probe of a bad experiment, he in all probability would have anticipated the discovery of Ingen-Housz.

Some of you, no doubt, recollect the words of Goldsmith's famous description of his own bedroom and of the furniture of the inn—

> "The house where nut-brown draughts inspired."

And how his imagination stooped to trace the story of—

> "The chest that contrived a double debt to pay,
> A bed by night, a chest of drawers by day."

As to himself he tells us how—

> "A night-cap decked his brows instead of bay,
> A cap by night—a stocking all the day."

Green plants contrive a double debt to pay; they give off oxygen by day, and at night exhale CO_2.

How do the vast number of plants, the microbes, the bacteria without chlorophyll get oxygen? Most of them get it as we get it. Some, however, cannot live in pure oxygen and are anærobic, such as the micro-organisms that cause tetanus, malignant œdema, and those that set up butyric acid fermentation.

Pushing the matter still further, it is extremely probable that the oxidation processes in our tissues are largely due to the presence of oxydases.

This raises the question as to the part played by the nucleus of a cell in its respiratory processes.

Is the source of muscular energy to be sought in oxidation or cleavage processes in tissues? In some animals there is not a direct relation between the muscular work and oxygen consumed, though there is to heat production. Bunge, on this ground, thought that the intestinal parasites of warm-blooded animals must have their oxygen at a minimum. In the intestinal contents there is no estimable oxygen; there active reduction processes go on. Entozoa might get oxygen from O_2 diffusing from blood-vessels.

Bunge found that intestinal worms of the cat and pike can live in an alkaline solution of common salt, free from gases, under Hg, for four to six days. They made active movements, and gave off much CO_2.

Ascaris lumbricoides from the intestine of the pig lived four to six days in 1 per cent. boiled NaCl solution. It made little difference whether oxygen or hydrogen was passed through the fluid. They lived seven to nine days if fluid was saturated with carbon dioxide, so that they have accommodated themselves to high percentages of carbon dioxide.

They give off to the fluid valerianic acid, an acid with a characteristic butyric acid odour. These worms contain a very large quantity of glycogen, the dry body yielding 20 per cent. to 34 per cent. of this carbohydrate.

100 grams Ascaris, placed in boiled normal saline solution, used per day—

0·7 gram glycogen,
0·1 ,, sugar,
No fat;

and yielded—

0·4 gram CO_2
0·3 valerianic acid.

It would seem that glycogen had split into CO_2, and valerianic acid—

$$4C_6H_{12}O_6 = 9CO_2 + 3C_5H_{10}O_2 + 9H_2$$
$$720 = 396 + 306 + 18.$$

Is it a genuine fermentation?

Weinland found that he could express by Buchner's method a substance, "zymase," which could split glycogen into CO_2 and valerianic acid.

Turning now to respiration in invertebrate animals, and dealing first with those which live in water, let us see some of the contrivances by which this end is achieved. The mechanisms are but means to an end. The ultimate union of oxygen, and the discharge of carbon dioxide with the liberation of energy, occur in the protoplasm of the cell itself.

There are two distinct processes, and it may be that the oxygen is introduced by one portal and the carbon dioxide got rid of by another, or it may be that one portal may do for both processes—the letting in of oxygen and the giving off of carbon dioxide.

Although the principle itself is simple, the variety of mechanisms adopted by nature to secure this double function is remarkable. Let us glance at some of the mechanisms proceeding from the simple to the complex, and first with regard to those animals that live in water.

Consider the oceanic fauna. It is immense both from the point of view of number and variety. Save insects and certain groups of molluscs, all invertebrates are aquatic. Amongst vertebrates, fishes have aquatic respiration, and some mammals, *e.g.* cetaceans or whales, have water as their sphere of existence, though they depend on the air for their respiratory oxygen.

The evolution from an aquatic to an aërial mode of existence can be traced in the animal kingdom, and may even be seen within limits in the history of certain species.

Every living cell, animal or vegetable, requires for its continued existence a supply of oxygen, and every living cell exhales carbon dioxide. The exchange of these two gases between the fluids of the body and the outer medium is the process of respiration. The simplest form of respiratory exchange occurs where there is no specially differentiated organ or mechanism for this purpose, so-called diffuse respiration. The whole surface of the organism in a watery medium may be concerned in this respiratory exchange. This is only possible, however, so long as the boundary surface, skin, or otherwise is permeable to gases, and no great respiratory exchanges are necessary.

Before showing you some lantern slides, I should like to point out how one process is made to aid another.

Motion associated with respiratory processes.

Ciliary motion with respiration and the capture of prey for food.

The old idea of one function for an organ is exploded. One speaks of one man one vote. One man one value. It is not really so.

With Shelley we may say—

"Nothing in this world is single;
All things, by a law Divine,
In each other's being mingle."

As regards the surfaces for these respiratory exchanges for diffuse respiration, it may take place through the inner surface of the body cavity of cœlenterates, the under surface of the bell of a medusa, the tentacles of an echinus, the respiratory tree at the hind gut of the sea cucumber, or the intestine of the young of the dragon fly, or by the intestinal mucous membrane of the mites which have no lungs or other directly respiratory organ. In the higher animals we have tracheæ, gills and lungs.

In some animals, the respiratory mechanism is closely related to the motor apparatus, as in some crustacea. In some mollusca the nutritive and respiratory mechanisms are closely related. In the highest of all there is central apparatus—gills or lungs—for the respiratory exchange between the blood and the air, and a circulatory apparatus for carrying the blood to and from the respiratory organs. The adaptivity of insects to varied conditions of oxygen supply is marvellous.

Before showing some classical experiments and illustrating the principles already laid down, I should like again to direct your attention to the association of several processes with respiratory mechanisms.

[The lecture was illustrated by means of lantern slides, showing the respiratory mechanisms from the lowest to the highest animals, and also by a number of experiments dealing with the chemical exchanges in the process of respiration. Lastly, the classical experiment of John Hunter, on the pneumaticity of the bones of birds, was shown in the duck. A candle flame was extinguished when held in front of the divided trachea, when air was blown into the divided humerus bone of the wing.]

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

ON June 27, Amherst College, Massachusetts, conferred the degree of M.A. upon Mr. Lundin, of Messrs. Alvan Clark and Sons, the following being President Harris's characterisation:—"CARL AXEL ROBERT LUNDIN: Scientific expert in cutting and fashioning glasses of great telescopes. He has done important work on the large objectives of Russia, of the Lick and Yerkes observatories, and lately on the 18-inch objective of the Amherst College Observatory, which is wholly his work. In 1854 Amherst conferred the degree of Master of Arts on Alvan Clark, who had built our first telescope. The same degree, for a similar service, is conferred on his successor, who has kept pace with the progress of astronomical science."

AN interesting inquiry as to the representation of science in the principal public libraries of Paris is being made by the *Revue Scientifique*, and the results are published week by week, from July 1 onwards, in the form of letters and opinions from the principal librarians and professors of science in France. The opinion is generally expressed that an unsatisfactory state of affairs exists in libraries such, for instance, as the Bibliothèque nationale and the library of the University of Paris owing to the fact that the librarians are almost exclusively graduates in arts and letters, and ignorant of the requirements of men of science. It thus happens that, the available funds